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Orofacial orthopaedics: background and possibility of combination with aligners.

Part 2



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Key words aligner orthodontics, Fränkel appliance, functional orthodontics, Invisalign, orofacial orthopaedics

Orofacial orthopaedics is a well proven treatment option in the young patient, often followed by fixed multibracket appliance treatment in a second phase. Nowadays, aligner orthodontics allow a treatment alternative to multibracket appliances, offering fewer potential side effects and more comfortable and aesthetic treatments for the patient. The following article describes several options of functional orthodontics in combination with aligner treatment.

Introduction

Mandibular condylar cartilage is the tissue with the greatest growth in the craniofacial complex, and is associated with maxillofacial skeleton morphogenesis and temporomandibular joint function. The condylar process grows in a wide range of directions from anterosuperior to posterior, resulting in highly diverse mandibular growth and morphology¹. Growth of the mandibular condyle contributes not only to increased mandible size, but also to anteroinferior

displacement (transposition) of the mandible. Growth of the craniofacial skeleton largely influences occlusal relationships, jaw relationships and orofacial functions²⁻⁹.

Functional appliances such as the Bionator, Activator or the Fränkel functional regulator allow such growth to be influenced, and they have been used for years with success in orthodontics¹⁰⁻¹².

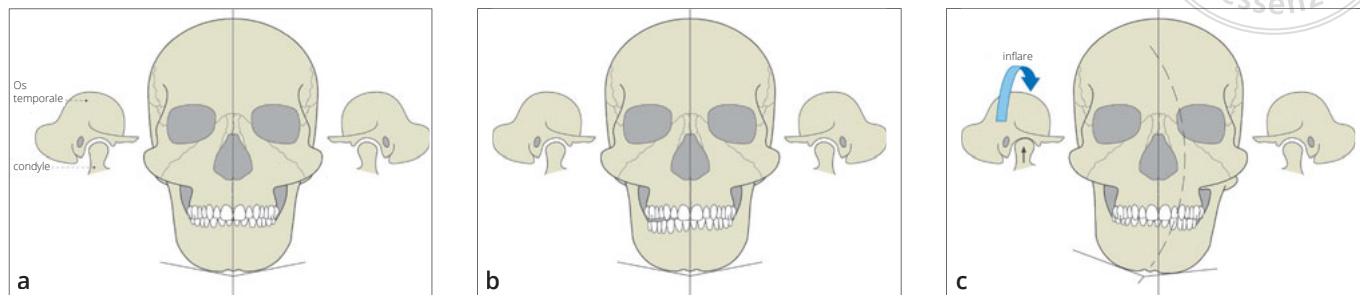
Face mask therapy such as with the Delaire mask has been reported to improve skeletal Class III malocclusions by a combination of skeletal and dental changes¹³. The effects of the Delaire mask are due to the changes of the mandibular plane angle and anterior lower and total face heights, changes that are reportedly reflected in a more balanced profile¹⁴. Cozza et al¹⁵ described the benefits of the Delaire face mask and Bionator III treatment as effective tools for correcting skeletal Class III malocclusions caused by maxillary retrognathism in the early mixed dentition.

Aligner orthodontics can be optimally combined with functional orthodontics in growing patients, especially when the aim is to treat orthodontically and orthopedically at the same time. This combination is only possible with aligners and a Fränkel functional regulator (FR) (the aligner therapy to correct the incorrect tooth position and the FR therapy to correct the incorrect skeletal jaw position). Since the FR is not supported on teeth with an occlusal relief such as an activator or Bionator, it can be combined with aligners in the maxillary and mandibular arch at the same time. This article reports simultaneous treatment with aligners and FR, as

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Figs 1a to c (a) The occlusal contacts are equal on both sides with a physiological temporomandibular joint (TMJ) and temporal bone. (b) Occlusal contact in a physiological condyle position only on the left, with a lack of posterior support on the right. (c) In habitual occlusion, the patient has occlusal contacts on the right and left, with a compression of the TMJ on the right and an inflare of the temporal bone (reproduced from Schupp et al²⁰).

well as a combination such as pretreatments with functional orthodontic devices followed by aligner treatment.

Part 1 by Blank-Lubarsch et al¹⁶ discussed the basic principles of orthopaedic treatment using the FR, and these are briefly repeated below.

The most important task of functional orthodontics and orofacial orthopaedics is the learning of functional pattern, the 'Roux Principle'. Changes in neuromuscular behaviour result from a process of learning¹⁷. Insufficient development of the orofacial muscles leads to insufficient development of the mandible and or maxilla¹⁷. Pathological neuromuscular patterns need to be changed first. Every modification of muscle pattern is accompanied with a change in the brain, especially in the basal ganglia. The basal ganglia select motor-cognitive- and emotional in- and output and ensure allostasis. Receptors from the periodontal ligament, bilaminar zone and muscles send information into the central nervous system, including into the basal ganglia. New adaption of the muscles is followed by a new relationship of the mandible to the maxilla, with direct connection to the musculoskeletal system^{18,19}.

The FR is a highly functional appliance, working with functional and neuromuscular stimuli and without pressure. The principles of the FR were explained in detail in Part 1¹⁶: there is a pulling force on the periosteum and pressure elimination from muscles that are not activated.

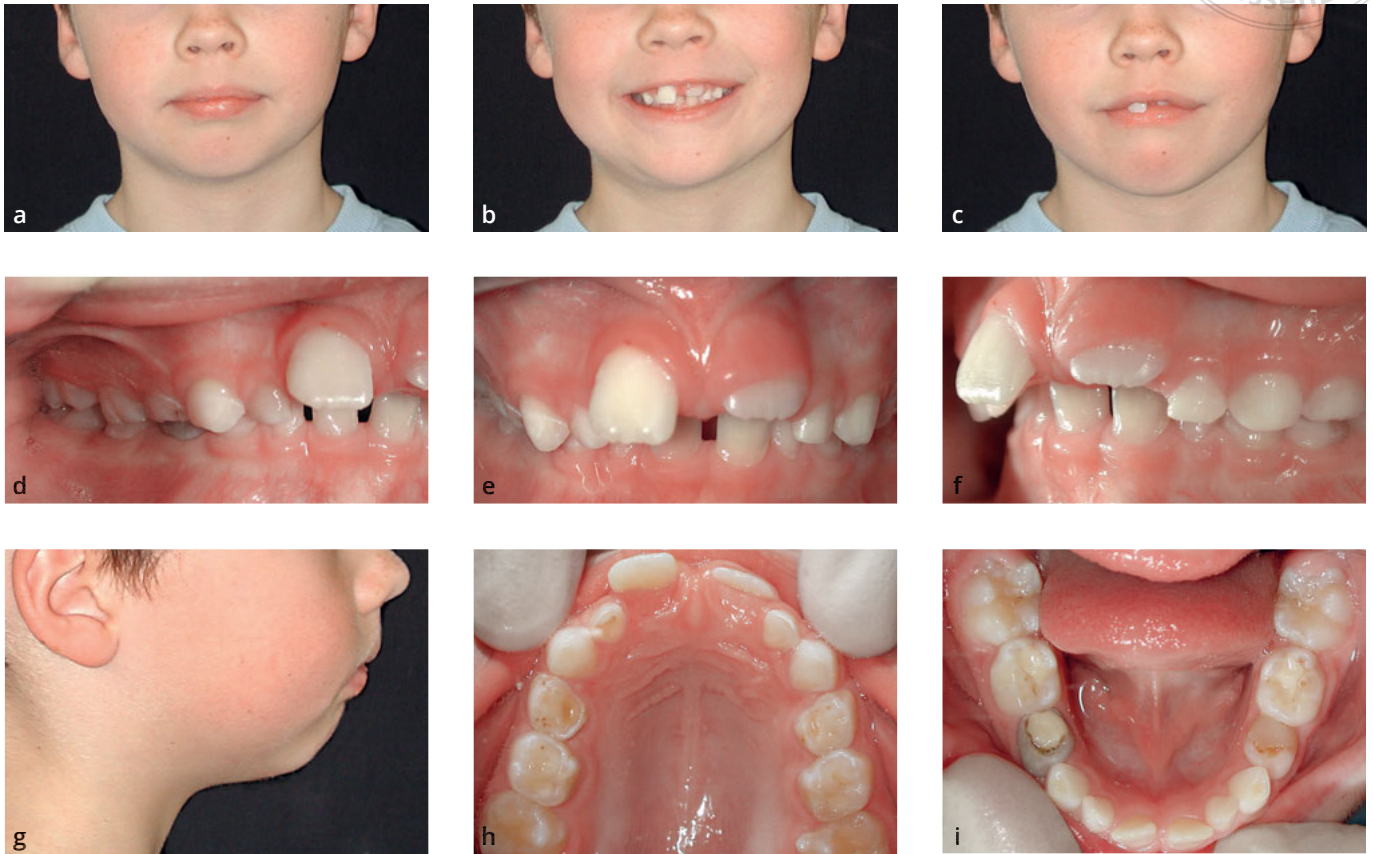
A perfect impression of not only the teeth, but also the entire vestibulum and the sublingual space is necessary to produce a functional FR. In cases using the FR in combination with aligner orthodontics, the buccal shields of the appliance are slightly reduced. The frenula should be clearly visible in the impression or scan. When treating the man-

dibular retrognathic position, the mandible is developed anteriorly in small steps. In addition to the sagittal orthopaedic adjustment, the vertical adjustment should also be taken into account. To do this, a physiological vertical overlap is set; if necessary, a slightly higher setting with a low vertical overlap in the deep bite takes place; in the open bite, the blocking should be as low as possible. It is important to pay attention to the vertical adjustment of the right to the left side (Fig 1). If there is a height difference that is associated with an impact on the skull and often with a descending disorder, this should be adjusted with the therapeutic construction bite²¹.

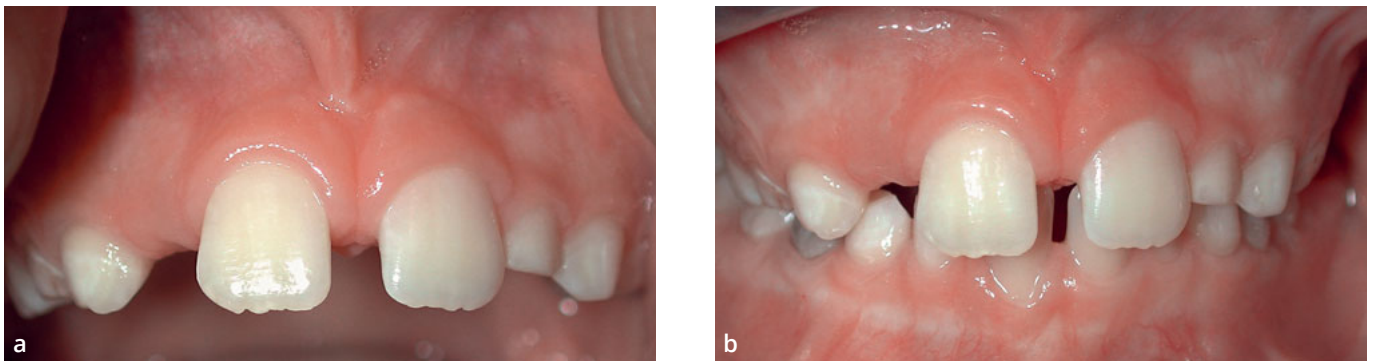
Aligner treatment has become a valuable treatment option for fixed appliances, allowing all types of tooth movement in every malocclusion²². Aligner treatment permits several treatments, such as mandibular advancement in growing patients²³ or space opening in young patients to avoid potential extraction treatment²⁴. Even in adult class III patients, distalisation in the mandible offers treatment options, as described in the literature^{25,26}. The present authors' experience is that a combination of early functional treatment in young patients followed by or combined with aligner therapy reduces treatment time and helps to avoid complicated and complex adult treatments.

Patient 1: Class II, pretreatment with a functional regulator type 1 followed by Invisalign treatment

At age 8 the patient presented with a Class II relationship with increased horizontal and vertical overlap, rotations



Figs 2a to i Extra- and intraoral situation at the start of treatment with early mixed dentition at the age of 8 years: Class II relationship with increased horizontal and vertical overlap, rotation of maxillary incisors. Due to the prominent frenulum, the patient showed a diastema mesial of teeth 11 and 21. The lip closure was incompetent, displaying tooth 11 with lip positioning beneath tooth 11.



Figs 3a and b Situation after frenectomy (Dr M Bäumer, Cologne).

and space in the maxillary anterior teeth with a large diastema between the central incisors due to a heavily inserting frenulum. The extraoral situation demonstrated an incompetent lip closure with showing of the maxillary right central incisor, and a retruded chin position (Fig 2). The treatment plan included myofunctional therapy and functional ortho-

dontic treatment with a FR type 1. The patient was advised to wear the appliance 16 hours a day. Due to the heavily inserting frenulum, the dental practitioner advised frenectomy, which was performed by the periodontist (Dr M Bäumer, Cologne) at age 10 (Fig 3). After improvement of the lip closure and sufficient advancement of the mandible



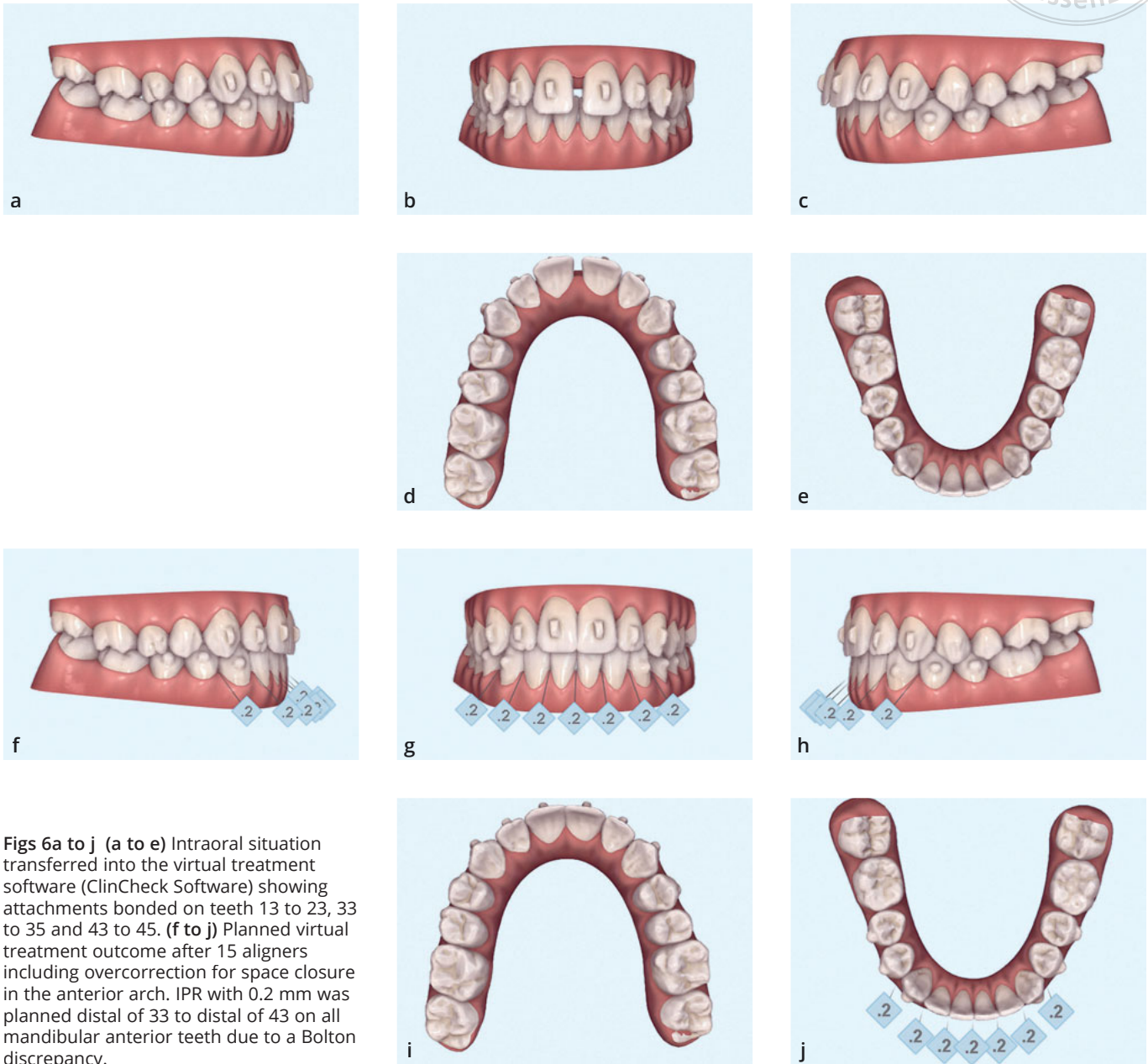
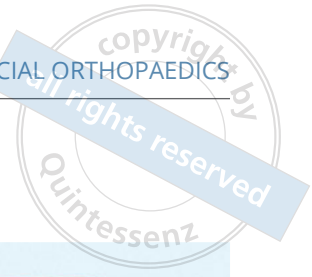
Figs 4a to c Extra- and intraoral situation after eruption of more permanent teeth at age 11. Spaces can be seen in the maxillary anterior region, and (a) shows the used functional regulator type 1 appliance in situ.



Figs 5a to i Extra- and intraoral situation at the start of the Invisalign treatment. The extraoral pictures show a harmonious profile with competent lip closure. Intraoral vertical bonded attachments on teeth 13 to 23, and horizontal attachments on teeth 33 to 35 and 43 to 45 have already been applied on teeth. The panoramic radiograph prior to bonding of the attachments shows no pathologies (i).

into a Class I relationship, the patient reduced the wearing time to night time only. Figure 4 shows the extra- and intraoral situation after eruption of more permanent teeth at age 14 with the FR in situ. Figure 5 shows the extra- and intraoral situation after eruption of all permanent teeth and planning of the Invisalign treatment at age 14, in a perfect Class I relationship due to the pretreatment with the func-

tional appliance. There were still spaces in the maxillary anterior region with a diastema between the maxillary central incisors. The panoramic radiograph (Fig 5i) showed no pathology. A lateral cephalogram was not taken as it was denied by the patients' parents. With the start of the Invisalign (Align Technology, San Jose, CA, USA) treatment, vertical attachments were bonded on teeth from the maxillary



Figs 6a to j (a to e) Intraoral situation transferred into the virtual treatment software (ClinCheck Software) showing attachments bonded on teeth 13 to 23, 33 to 35 and 43 to 45. **(f to j)** Planned virtual treatment outcome after 15 aligners including overcorrection for space closure in the anterior arch. IPR with 0.2 mm was planned distal of 33 to distal of 43 on all mandibular anterior teeth due to a Bolton discrepancy.

left to right lateral incisors, and horizontal attachments on the mandibular left canine to second premolar and mandibular right canine to second premolar, as shown in Fig 5. Scans were taken and the intraoral situation transferred into the ClinCheck Software (Figs 6a to 6e). The ClinCheck simulation showed the planned final outcome with space closure in the maxillary anterior region and overcorrection

of the space closure. Minimal interproximal reduction (IPR) (0.2 mm on the distal aspect of the mandibular left canine and all anterior teeth to the distal aspect of the mandibular right canine) had to be performed on mandibular anterior teeth due to a Bolton discrepancy (Figs 6f to 6j). Figure 7 shows the final outcome after treatment with 15 aligners in the maxilla and 12 aligners in the mandible, with an overall



Figs 7a to j Extra- and intraoral situation after the functional pretreatment followed by the Invisalign therapy. The patient demonstrates a harmonious extraoral profile with Class I relationship with aligned arches and functional horizontal and vertical overlap.



Figs 8a to c Comparison of extraoral profile prior to treatment (a), after functional pretreatment (b), and after Invisalign therapy (c).

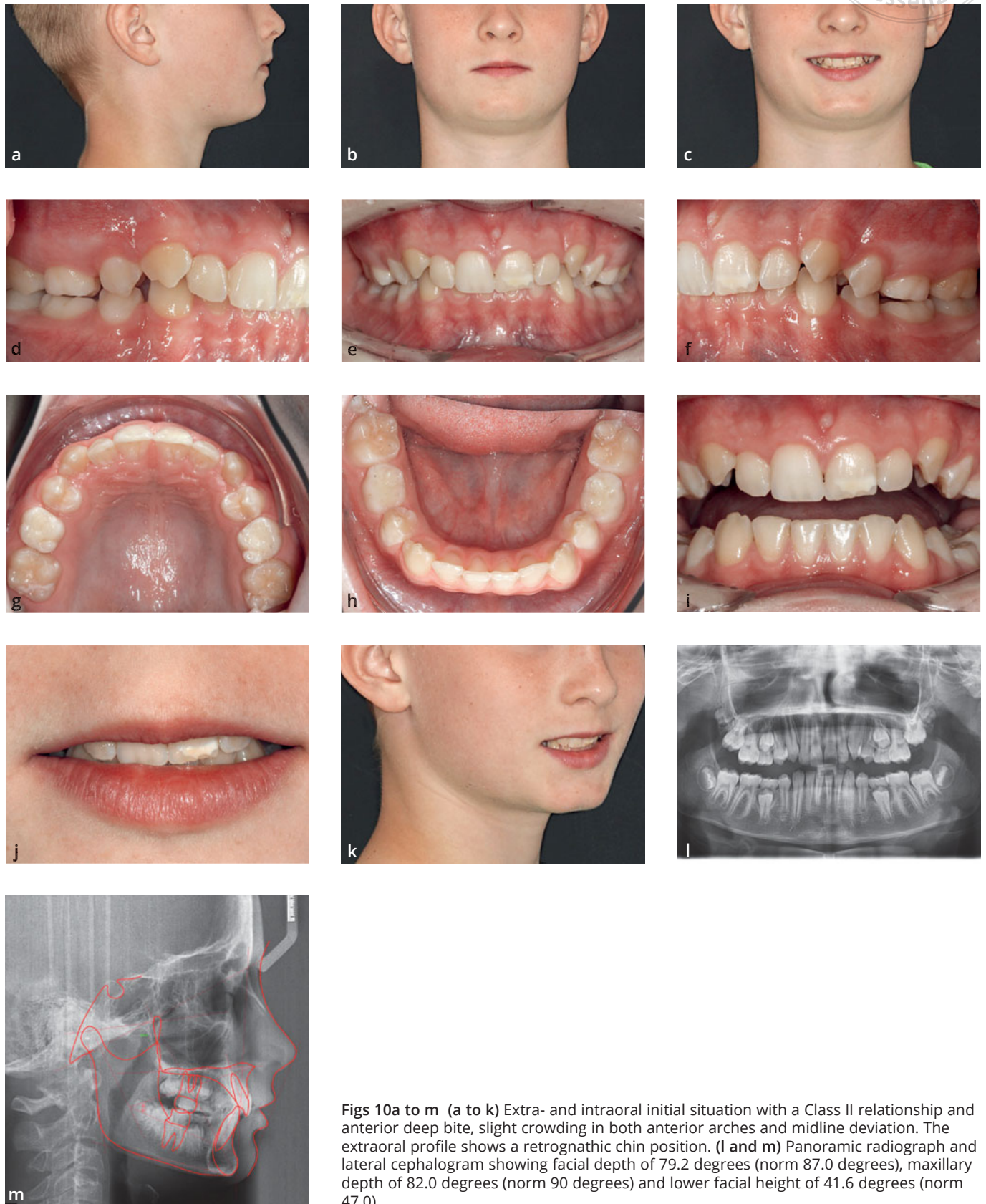


Figs 9a to i Course of treatment. (a to c) Start of functional orthodontics with functional regulator. (d to f) Start of Invisalign treatment. (g to i) Final result after pretreatment with functional orthodontics followed by Invisalign therapy.

treatment time of 7 months and a change of aligners every 2 weeks (according to a former protocol – nowadays change is advised every 7 days in most patients). The intraoral situation showed a Class I relationship with aligned arches and functional horizontal and vertical overlap. The extraoral profile showed an improvement of the retruded chin position and a harmonious aesthetic line. Figure 8 demonstrates the comparison of lip profile prior to treatment, after functional pretreatment and after Invisalign therapy. Figure 9 shows the course of treatment prior to functional orthodontics, before the alignment of the arches with the Invisalign therapy, and the treatment outcome after the combination of pretreatment with a functional appliance followed by Invisalign treatment.

Patient 2: Class II, combination of functional regulator type 2 with Invisalign system

A 12-year-old patient presented with a late mixed dentition in a Class II, division 2 relationship. The patient was showing a vertical overlap with midline deviation in the mandibular arch, rotations and crowding in the anterior region with retrally positioned maxillary incisors and an excessive lower curve of Spee (Fig 10 and Table 1). The extraoral profile showed a retrognathic chin position (Figs 10l and 10m) with a facial depth of 79.2 degrees (norm 87 degrees), maxillary depth of 82.0 degrees (norm 90 degrees) and lower facial height 41.6 degrees (norm 47 degrees).



Figs 10a to m (a to k) Extra- and intraoral initial situation with a Class II relationship and anterior deep bite, slight crowding in both anterior arches and midline deviation. The extraoral profile shows a retrognathic chin position. **(l and m)** Panoramic radiograph and lateral cephalogram showing facial depth of 79.2 degrees (norm 87.0 degrees), maxillary depth of 82.0 degrees (norm 90 degrees) and lower facial height of 41.6 degrees (norm 47.0).

Table 1 Cephalometric results at initial situation

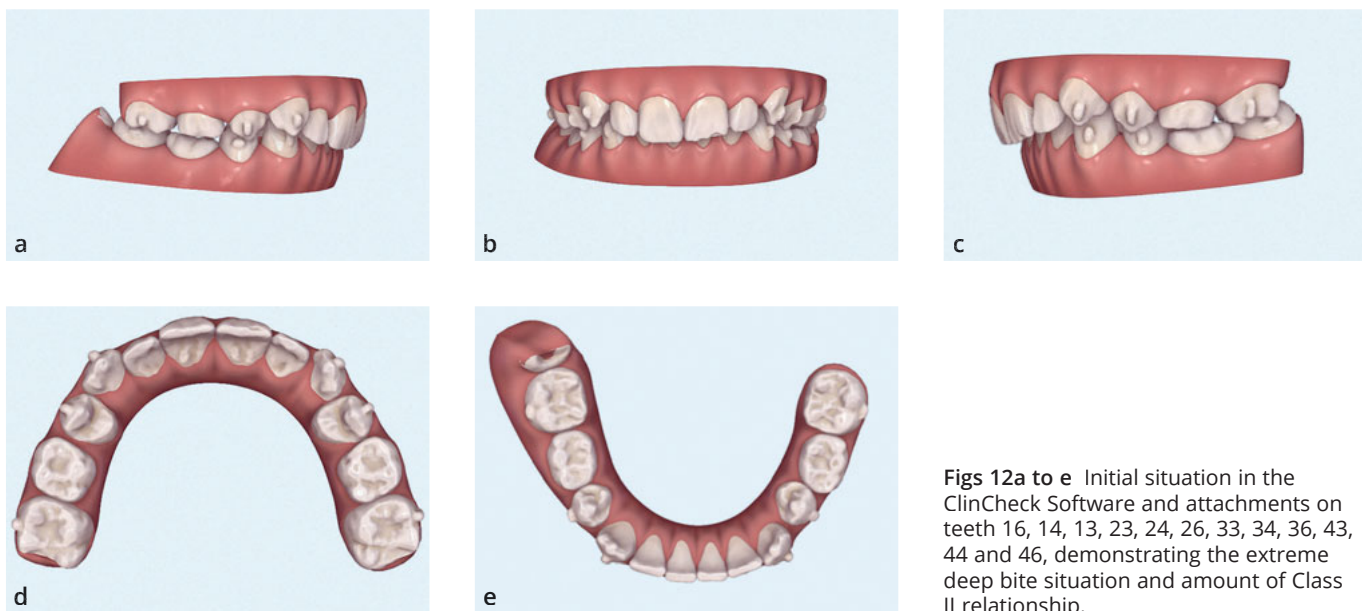
Variable	Norm	Result 5 July 2016	Difference	Standard deviation																
				5	4	3	2	10	1	2	3	4	5							
Incisor horizontal overlap (mm)	2.5 ± 2.5	-10.9	-13.4	▲																
Incisor vertical overlap (mm)	2.5 ± 2.0	8.3	5.8																	
Interincisal angle (degrees)	130.0 ± 6.0	135.7	5.7																	
Convexity of A (mm)	1.2 ± 2.0	5.6	4.4																	
Lower facial height (degrees)	47.0 ± 4.0	41.6	-5.4																	
6. PTV distance (mm)	15.0 ± 2.0	10.4	-4.6																	
1- APo distance (mm)	1.0 ± 2.3	-6.7	-7.7																	
1. APo distance (mm)	3.5 ± 2.3	3.2	-0.3																	
1- APo angle (degrees)	22.0 ± 4.0	19.4	-2.6																	
1. APo angle (degrees)	28.0 ± 4.0	24.9	-3.1																	
XI-OcP (mm)	1.8 ± 3.0	14.2	12.4																	
XIPO-OcP angle (degrees)	24.5 ± 4.0	10.8	-13.7																	
LL-E plane (mm)	-1.2 ± 2.0	0.0	1.2																	
Upper lip length (mm)	24.0 ± 2.0	46.0	22.0																	
Lip embrasure - occlusal plane (mm)	-3.5	14.5	18.0																	
Facial (angle) depth (degrees)	88.0 ± 3.0	79.2	-8.8																	
Facial axis (degrees)	90.0 ± 3.0	89.5	-0.5																	
Conical angle (degrees)	68.0 ± 3.5	79.5	11.5																	
Mandibular plane (degrees)	27.2 ± 4.5	21.2	-6.0																	
Maxillary depth (degrees)	90.0 ± 3.0	82.0	-8.0																	
Maxillary height (degrees)	54.0 ± 3.0	61.3	7.1																	
Palatal plane (degrees)	1.0 ± 3.5	4.7	3.7																	
Cranial deflection (degrees)	27.0 ± 3.0	20.5	-6.5																	
Cranial length anterior (mm)	55.0 ± 2.5	114.3	59.3																	
Facial height posterior (mm)	55.0 ± 3.3	142.2	87.2																	
Ramus position (degrees)	76.0 ± 3.0	66.1	-9.9																	
Porion location (degrees)	39.0 ± 2.2	81.4	42.4																	
Mandibular arc (degrees)	28.0 ± 4.0	40.1	12.1																	
Corous length (mm)	71.4 ± 2.7	126.5	55.1																	

Although a pretreatment with a functional appliance is often the first treatment choice, in this patient it was decided to combine directly the aligner treatment with the functional treatment. Figure 11 shows the intraoral situation with inserted attachments on the maxillary right first molar, first premolar and canine, and maxillary left, first molar, first premolar and canine (teeth 16, 14, 13, 23, 24, 26, 33, 34, 36, 43, 44 and 46, according to FDI notation). Primary teeth 55, 65, 75 and 85 were still in situ. Figures 12a to 12e show the initial situation transferred into the ClinCheck Software with the inserted attachments, demonstrating the

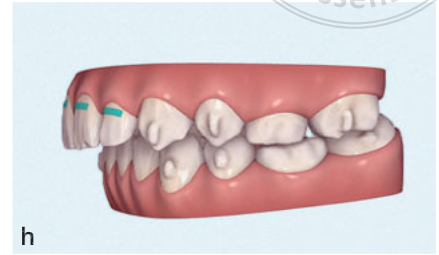
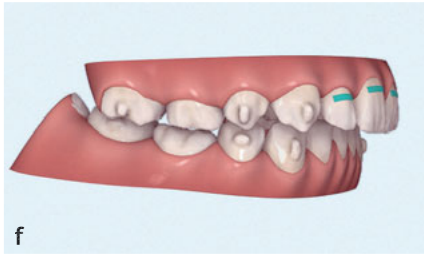
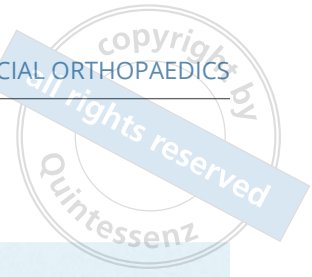
extreme deep bite situation and amount of Class II relationship. Figures 12f to 12j demonstrate the planned outcome after 20 aligners in the ClinCheck Software with power ridges on the maxillary incisors (teeth 12 to 22) for torque. The mandibular incisors had been intruded and the horizontal overlap was increased to 7 mm to allow mandibular advancement with the additional FR. Figures 12k to 12o show the potential planned outcome in the ClinCheck Software after virtual final mandibular set forward into a Class I relationship, demonstrating the mandibular growth due to the FR.



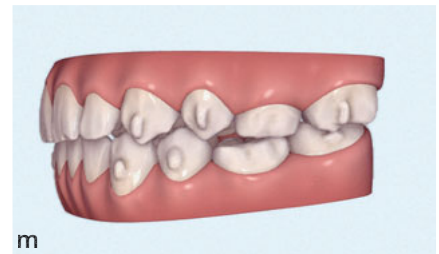
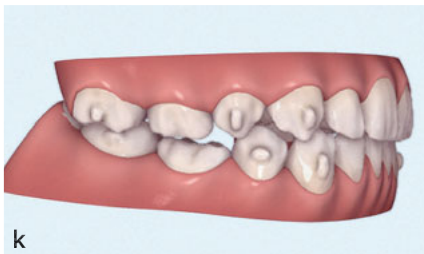
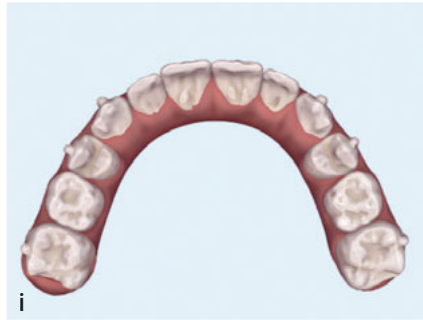
Figs 11a to f Intraoral situation at the beginning of the Invisalign therapy with bonded attachments on teeth 16, 14, 13, 23, 24, 26, 33, 34, 36, 43, 44 and 46. Primary teeth 55, 65, 75 and 85 were still in situ. The patient showed a vertical overlap with retrally positioned maxillary incisors in Class II relationship. The lower curve of Spee was excessive with extruded mandibular anterior teeth.



Figs 12a to e Initial situation in the ClinCheck Software and attachments on teeth 16, 14, 13, 23, 24, 26, 33, 34, 36, 43, 44 and 46, demonstrating the extreme deep bite situation and amount of Class II relationship.



Figs 12f to j Planned outcome after 20 aligners in the ClinCheck Software with power ridges on teeth 12 to 22 for torque on maxillary incisors. The mandibular incisors have been intruded with the horizontal overlap increased up to 7 mm.

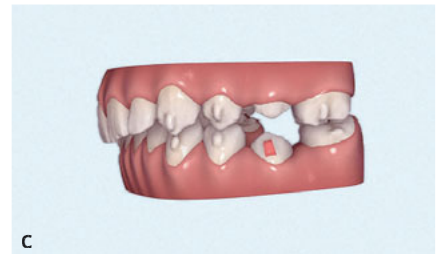
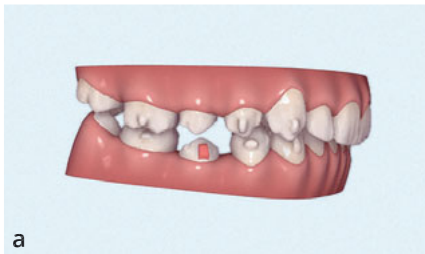


Figs 12k to o Potential planned outcome in the ClinCheck Software after mandibular set forward into a Class I relationship, demonstrating the virtual mandibular advancement with the functional regulator.





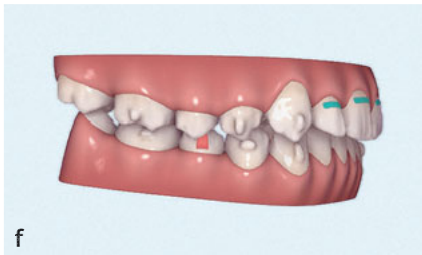
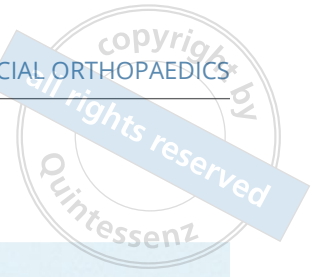
Figs 13a to e Intraoral situation after eruption of second premolars and start of next Invisalign phase. The patient still demonstrates a Class II relationship due to anterior precontacts.



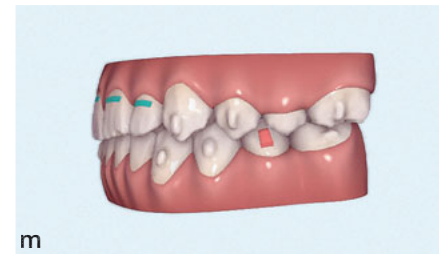
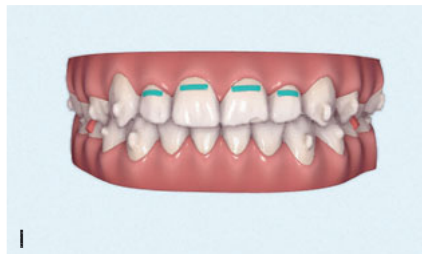
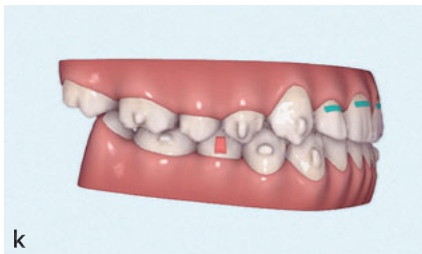
Figs 14a to e Intraoral situation at start of second phase with Invisalign treatment after eruption of second premolars. Vertical rectangular attachments have been planned on mandibular second premolars for additional anchorage.

After 20 weeks of treatment time, new scans were taken, which included the erupting mandibular left first and second premolars (teeth 35 and 45), and again transferred into the ClinCheck Software. Improvement of the Class II relationship was visible, due to the anterior precontact, and no further advancement was possible (Fig 13). The initial situation of the next phase transferred into the ClinCheck Software is shown in Figs 14a to 14e. According to the first

phase, further torque of maxillary anterior teeth and intrusion of mandibular anterior teeth with an increase of the horizontal overlap was the treatment goal (Figs 14f to 14j). Figures 14k to 14o demonstrate again a possible outcome after virtual mandibular advancement into a Class I relationship simulating the FR effect. Figure 15 shows the intraoral situation after the second phase of treatment, still with anterior precontact and a Class II relationship. Scans



Figs 14f to j Final planned outcome in the second ClinCheck Software phase after additional 23 aligners. Power ridges were again inserted on maxillary teeth 12 to 22 and the arches aligned. Horizontal overlap was again increased up to 5 mm to obtain sufficient space for the virtual mandibular advancement with the additional functional regulator.



Figs 14k to o Final planned outcome in the second ClinCheck Software phase after mandibular virtual advancement into a Class I relationship simulating the effect of the functional regulator.

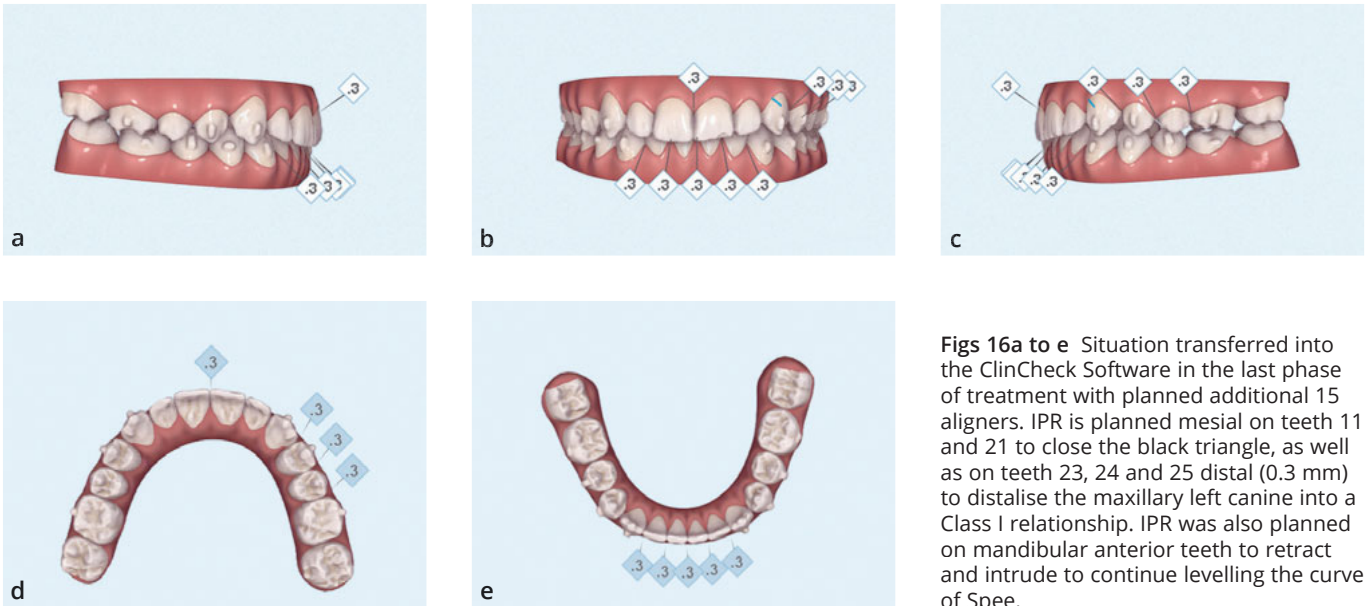


were taken for a third phase of treatment to torque further maxillary anterior teeth and intrude mandibular anterior teeth and level the lower curve of Spee. According to the first and second phases, Figs 16a to 16e demonstrate the situation transferred into the ClinCheck Software with additional 15 aligners planned (Figs 16f to 16o). IPR was planned mesially on the maxillary central incisors to close the 'black triangle', as well as on the maxillary left canine to second

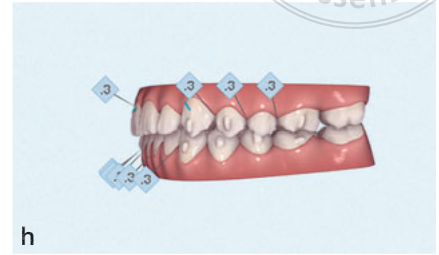
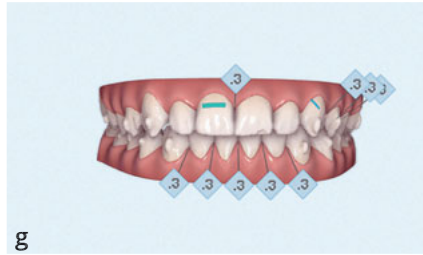
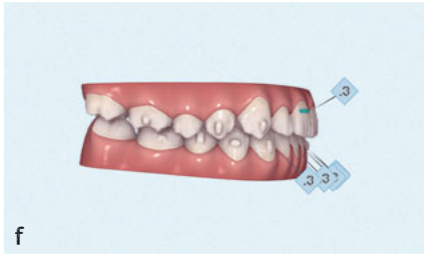
premolar (teeth 23, 24 and 25) distally (0.3 mm) to distalise the maxillary left canine into a Class I relationship. IPR was also planned on the mandibular anterior teeth to retract and intrude, to continue levelling the curve of Spee. A precision cut was inserted on the maxillary left canine (tooth 23), and the gingival margin was set up due to the button on tooth 36 for the unilateral Class II elastic wear on the left side (Figs 16f to 16o).



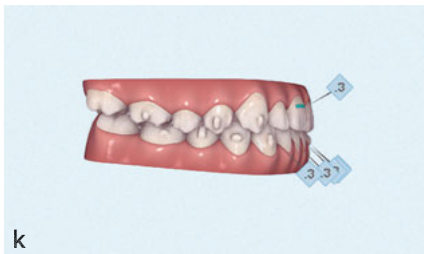
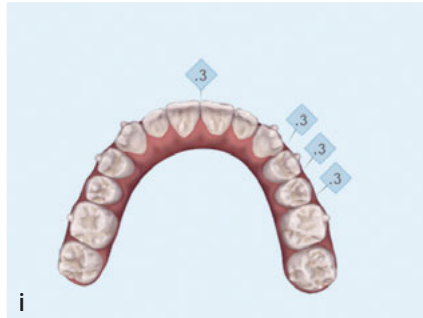
Figs 15a to f Intraoral situation after the second phase of treatment still with anterior precontact and a Class II relationship. Scans were taken for a third phase of treatment to torque further maxillary anterior teeth and intrude mandibular anterior teeth and level the lower curve of Spee.



Figs 16a to e Situation transferred into the ClinCheck Software in the last phase of treatment with planned additional 15 aligners. IPR is planned mesial on teeth 11 and 21 to close the black triangle, as well as on teeth 23, 24 and 25 distal (0.3 mm) to distalise the maxillary left canine into a Class I relationship. IPR was also planned on mandibular anterior teeth to retract and intrude to continue levelling the curve of Spee.



Figs 16f to j Planned outcome in the last phase of treatment with alignment of the arches prior to the simulated unilateral left mandibular set forward after 15 aligners. A precision cut was inserted on tooth 23, and the gingival margin was set up due to the button on tooth 36 for the unilateral Class II elastic wear on the left side.



Figs 16k to o Final planned outcome after a unilateral set forward of the mandible on the right side into a Class I relationship.

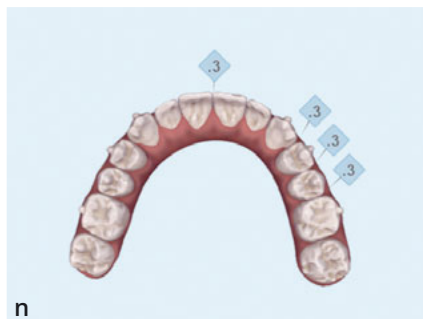




Fig 17a to f Intraoral situation with the last aligner (aligner 15) in situ showing perfect aligner fitting. The button on tooth 36 has already been removed on the pictures.

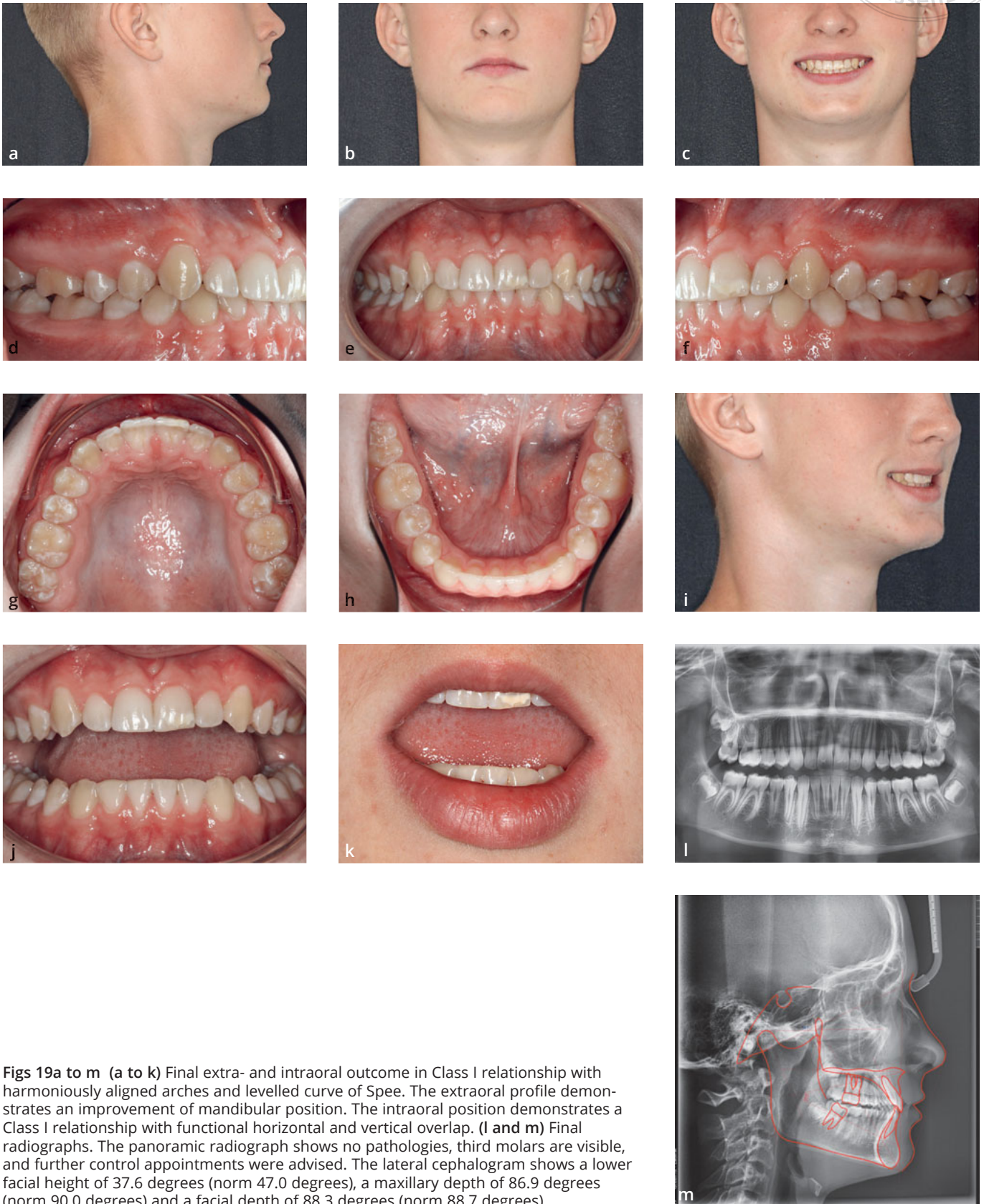


Figs 18a to c Intraoral situation with aligner 15 in combination with the functional regulator in situ.

The intraoral situation with the last aligner (aligner 15) in situ showed perfect aligner fitting (Fig 17). Figure 18 shows the intraoral situation with aligner 15 in combination with the FR appliance in situ.

Figure 19 and Table 2 show the final extra- and intraoral outcomes in the Class I relationship with harmoniously aligned arches and levelled curve of Spee. The extraoral profile demonstrated an improvement of the mandibular position. Intraorally, the patient demonstrated a Class I relationship with functional horizontal and vertical overlap. Figures 19l and 19m demonstrate the final radiographs, showing no pathologies in the panoramic radiograph and that third molars were visible. Further control appoint-

ments were advised. The lateral cephalogram showed a lower facial height with 37.6 degrees (norm 47 degrees), a maxillary depth of 86.9 degrees (norm 90 degrees) and a facial depth of 88.3 degrees (norm 88.7 degrees) (Table 2). Figure 20 shows the final situation with aligned arches and marked occlusal contact points, demonstrating occlusal contact on posterior teeth and canines, without anterior precontact. Retention was performed with a lingual retainer in the mandible from the left to right first premolars (teeth 34 to 44) and a removable appliance in the maxilla during night-time only. Figures 21 and 22 show the course of treatment and improvements in the profile and intraorally from Class II, division 2 into a Class I relationship



Figs 19a to m (a to k) Final extra- and intraoral outcome in Class I relationship with harmoniously aligned arches and levelled curve of Spee. The extraoral profile demonstrates an improvement of mandibular position. The intraoral position demonstrates a Class I relationship with functional horizontal and vertical overlap. **(l and m)** Final radiographs. The panoramic radiograph shows no pathologies, third molars are visible, and further control appointments were advised. The lateral cephalogram shows a lower facial height of 37.6 degrees (norm 47.0 degrees), a maxillary depth of 86.9 degrees (norm 90.0 degrees) and a facial depth of 88.3 degrees (norm 88.7 degrees).



Table 2 Cephalometric results at 2 years of treatment

Variable	Norm	Result 30 July 2018	Difference	Standard deviation
				5 4 3 2 1 0 1 2 3 4 5
Incisor horizontal overlap (mm)	2.5 ± 2.5	-4.0	-6.5	
Incisor vertical overlap (mm)	2.5 ± 2.0	2.3	0.2	
Interincisal angle (degrees)	130.0 ± 6.0	131.6	1.9	
Convexity of A (mm)	0.8 ± 2.0	-1.4	-2.2	
Lower facial height (degrees)	47.0 ± 4.0	37.6	-9.4	
6_PTV distance (mm)	17.0 ± 2.0	16.6	-0.4	
1_APo distance (mm)	1.0 ± 2.3	-2.1	-3.1	
1_APo distance (mm)	3.5 ± 2.3	1.4	-2.1	
1_APo angle (degrees)	22.0 ± 4.0	21.6	-0.4	
1_APo angle (degrees)	28.0 ± 4.0	26.5	-1.5	
XI-OcP (mm)	1.8 ± 3.0	1.5	-0.3	
XIPO-OcP angle (degrees)	24.5 ± 4.0	14.8	-9.7	
LL-E plane (mm)	-0.8 ± 2.0	-2.3	-1.5	
Upper lip length (mm)	24.0 ± 2.0	22.0	-2.0	
Lip embrasure – occlusal plane (mm)	-3.5	6.9	10.4	
Facial (angle) depth (degrees)	88.7 ± 3.0	88.3	-0.4	
Facial axis (degrees)	90.0 ± 3.0	94.3	4.3	
Conical angle (degrees)	68.0 ± 3.5	75.4	7.4	
Mandibular plane (degrees)	27.2 ± 4.5	16.3	-10.9	
Maxillary depth (degrees)	90.0 ± 3.0	86.9	-3.1	
Maxillary height (degrees)	55.0 ± 3.0	57.3	2.3	
Palatal plane (degrees)	1.0 ± 3.5	2.0	1.0	
Cranial deflection (degrees)	27.0 ± 3.0	24.3	-2.7	
Cranial length anterior (mm)	55.0 ± 2.5	59.8	4.8	
Facial height posterior (mm)	55.0 ± 3.3	72.8	17.8	
Ramus position (degrees)	76.0 ± 3.0	70.0	-6.0	
Porion location (degrees)	39.0 ± 2.2	41.9	2.9	
Mandibular arc (degrees)	29.0 ± 4.0	40.6	11.6	
Corous length (mm)	74.6 ± 2.7	76.0	1.4	



Figs 20a and b Final maxillary and mandibular arch with marked occlusal contact points showing an equal posterior occlusal pattern without anterior contacts. For retention, a lingual retainer in the mandibular arch from 34 to 44 was inserted. The patient was wearing a maxillary removable aligner during night time for retention.



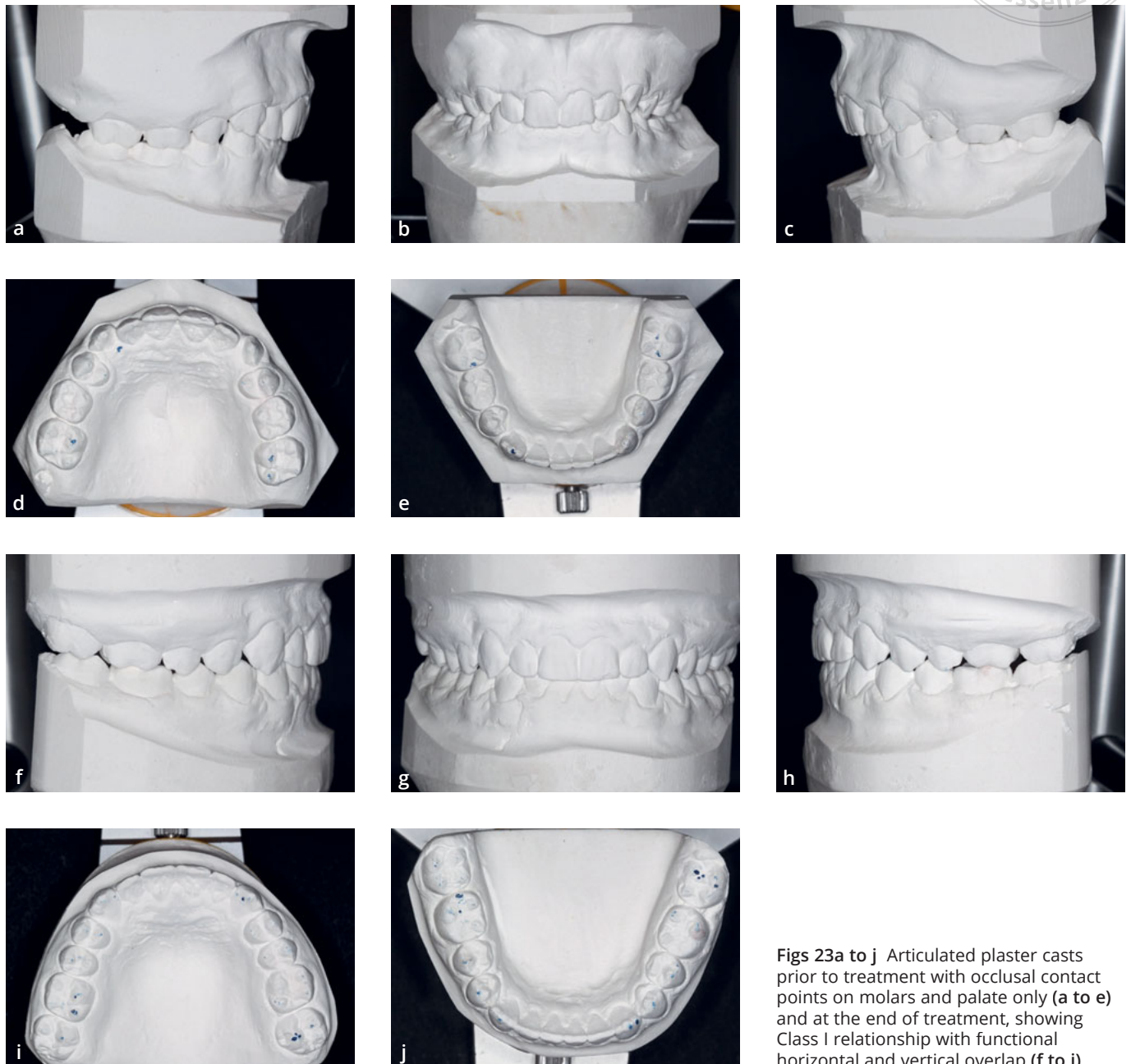
Figs 21a and b Course of treatment. (a) Extraoral profile prior to combination treatment of functional orthodontics and Invisalign. (b) After treatment combination of functional regulator and Invisalign.



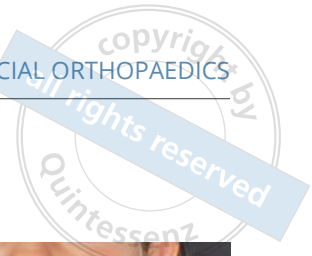
Fig 22a to i Course of treatment. (a to c) intraoral situation prior to combination treatment of functional orthodontics and Invisalign. (d to f) Intraoral situation during treatment combination of orthodontics and Invisalign. (g to i) After treatment combination of functional regulator and Invisalign.

with the combination of Invisalign treatment and functional appliance. Figure 23 demonstrates the comparison of the initial plaster casts in the articulator (Figs 23a to 23e) com-

pared to the final articulated plaster casts in a Class I relationship (Figs 23f to 23j).



Figs 23a to j Articulated plaster casts prior to treatment with occlusal contact points on molars and palate only (a to e) and at the end of treatment, showing Class I relationship with functional horizontal and vertical overlap (f to j).



Figs 24a to l Initial extra- and intraoral situation with anterior reverse articulation and open bite. The patient started to wear a Bionator followed by a functional regulator type 3 for 16 hours a day. The panoramic radiograph at the start of treatment showing no pathologies, and little space for eruption in the maxilla. The lateral cephalogram shows a lower facial height of 53.1 degrees (norm 47.0 degrees), a maxillary depth of 87.3 degrees (norm 90.0 degrees) and a facial depth of 8.5 degrees (norm 88.7 degrees).

Patient 3: Class III, pretreatment with a functional regulator type 3 followed by Invisalign treatment

The 8-year-old patient presented with an early mixed dentition with anterior open bite of 7 mm and reverse articulation (crossbite) tendency, rotations and slight spaces in the

anterior region. The extraoral pictures showed a Class III profile tendency with prominent chin and retrognathic maxilla, the lateral cephalogram showed a lower facial height of 53.1 degrees (norm 47.0 degrees), a maxillary depth of 87.3 degrees (norm 90.0 degrees) and a facial depth of 85.5 degrees (norm 88.7 degrees) (Fig 24 and Table 3).



Table 3 Cephalometric results at initial presentation

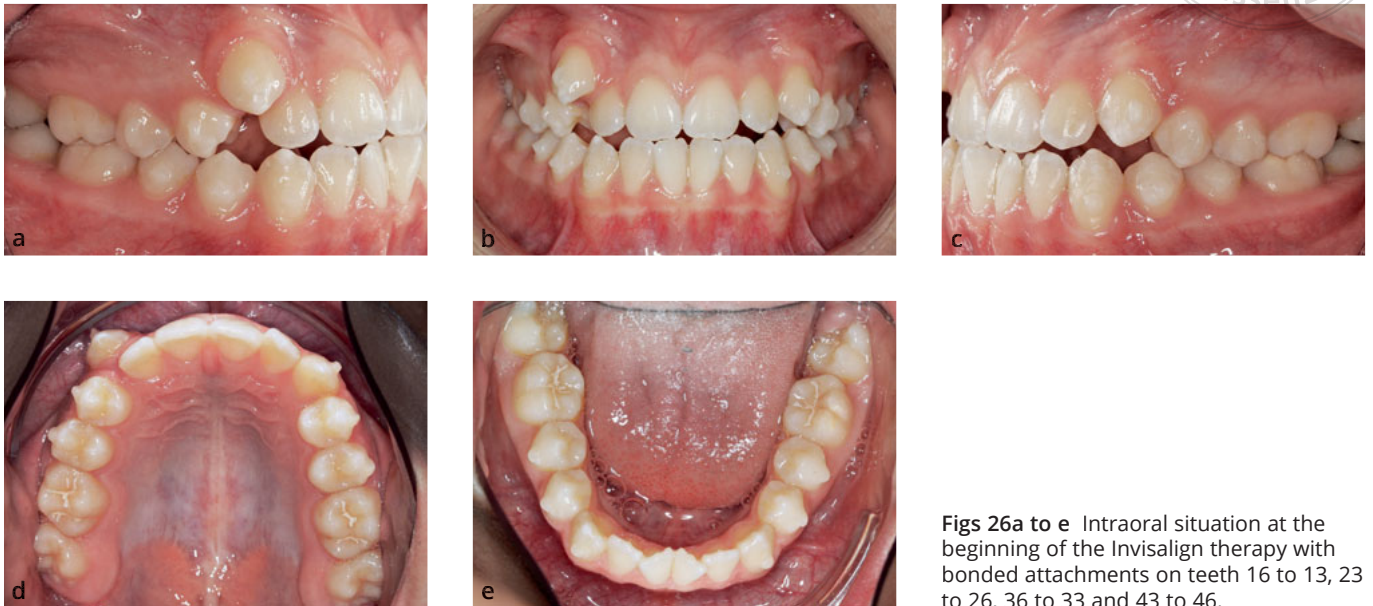
Variable	Norm	Result 23 May 2011	Difference	Standard deviation
				5 4 3 2 1 0 1 2 3 4 5
Incisor horizontal overlap (mm)	2.5 ± 2.5	1.6	-0.9	
Incisor vertical overlap (mm)	2.5 ± 2.0	-7.5	-10.0	
Interincisal angle (degrees)	130.0 ± 6.0	122.5	-7.5	
Convexity of A (mm)	2.0 ± 2.0	3.0	1.0	
Lower facial height (degrees)	47.0 ± 4.0	53.1	6.1	
6_PTV distance (mm)	11.0 ± 2.0	18.9	7.9	
1_APo distance (mm)	1.0 ± 2.0	9.6	8.6	
1_APo distance (mm)	3.5 ± 2.3	10.5	7.0	
1_APo angle (degrees)	22.0 ± 4.0	25.6	3.6	
1_APo angle (degrees)	28.0 ± 4.0	31.9	3.9	
XI-OcP (mm)	1.8 ± 3.0	16.8	15.0	
XIPO-OcP angle (degrees)	24.5 ± 4.0	13.1	-11.4	
LL-E plane (mm)	-2.0 ± 2.0	3.9	5.9	
Upper lip length (mm)	24.0 ± 2.0	50.5	26.5	
Lip embrasure – occlusal plane (mm)	-3.5	16.2	19.7	
Facial (angle) depth (degrees)	87.0 ± 3.0	85.5	-1.5	
Facial axis (degrees)	90.0 ± 3.0	88.1	-1.9	
Conical angle (degrees)	68.0 ± 3.5	64.4	-3.6	
Mandibular plane (degrees)	27.2 ± 4.5	30.1	2.9	
Maxillary depth (degrees)	90.0 ± 3.0	87.3	-2.7	
Maxillary height (degrees)	53.0 ± 3.0	57.3	4.3	
Palatal plane (degrees)	1.0 ± 3.5	3.1	2.1	
Cranial deflection (degrees)	27.0 ± 3.0	25.4	-1.6	
Cranial length anterior (mm)	55.0 ± 2.5	98.2	43.2	
Facial height posterior (mm)	55.0 ± 3.3	107.9	52.9	
Ramus position (degrees)	76.0 ± 3.0	76.0	0.0	
Porion location (degrees)	39.0 ± 2.2	61.7	22.7	
Mandibular arc (degrees)	26.0 ± 4.0	32.3	6.3	
Corous length (mm)	65.0 ± 2.7	117.6	52.6	

In a first treatment phase, a Bionator, which was anteriorly built up with increased composite width, helping to lead the tongue into a functional position at the palatal point of rest, helped to avoid tongue insertion in the incisor region and allowed further eruption of the anterior teeth for bite closure. The patient was advised to wear the Bionator during day and night time, if possible 16 hours a day. Myofunctional therapy was advised. After further closure of the bite, a FR type 3 was given to the patient, allowing further development of the maxilla. Figure 25 shows the situation after functional pretreatment of several years after

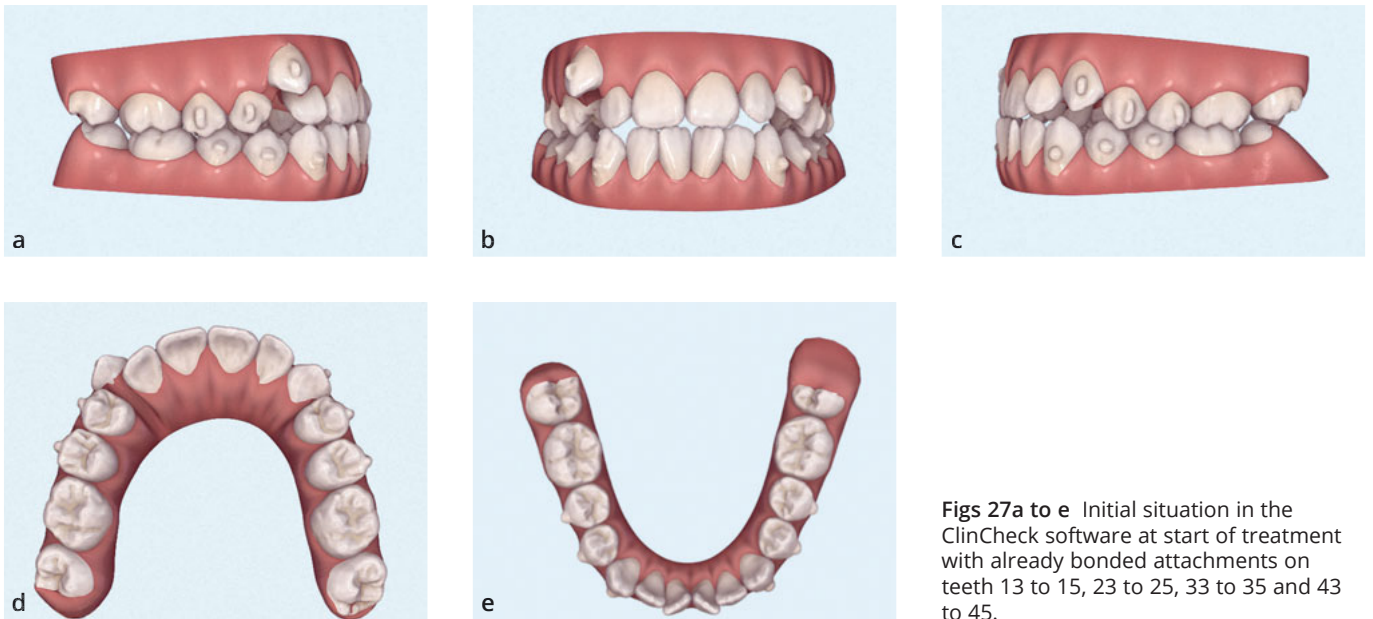
eruption of all permanent teeth. At age 12, the anterior reverse articulation has been almost solved, further permanent teeth have erupted, but the patient showed insufficient space for alignment, particularly with insufficient space for the maxillary right lateral incisor (tooth 13). To align the arches and gain further space for eruption of the permanent teeth, Invisalign treatment was started. For sufficient anchorage, attachments were bonded on all the lateral incisors and first and second premolars (teeth 13 to 15, 23 to 25, 33 to 35 and on 43 to 35) (Fig 26).



Figs 25a to k Situation after functional pretreatment with a Bionator followed by functional regulator type 3 and myofunctional therapy after eruption of all permanent teeth. The anterior open bite and reverse articulation was improved, but it was necessary to continue treatment to align the arches, extrude maxillary anterior teeth and end in a Class I relationship with functional horizontal and vertical overlap.



Figs 26a to e Intraoral situation at the beginning of the Invisalign therapy with bonded attachments on teeth 16 to 13, 23 to 26, 36 to 33 and 43 to 46.

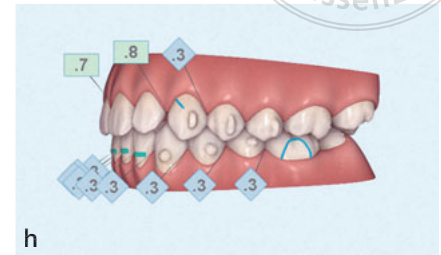
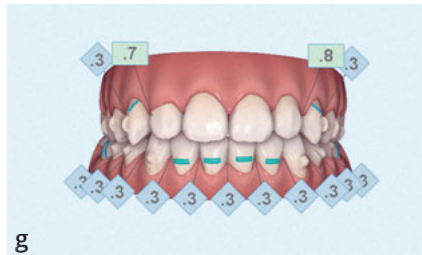
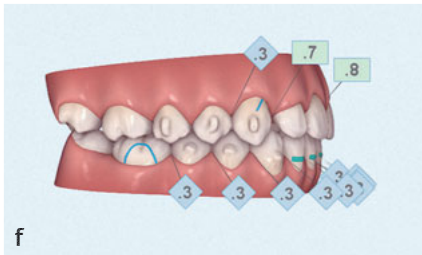
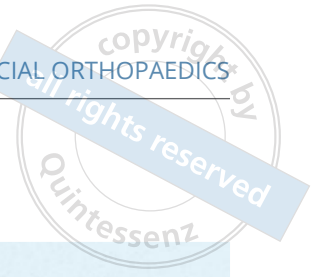


Figs 27a to e Initial situation in the ClinCheck software at start of treatment with already bonded attachments on teeth 13 to 15, 23 to 25, 33 to 35 and 43 to 45.

Figure 27 shows the transferred initial intraoral situation into the ClinCheck Software and the final planned virtual outcome with aligned arches in a Class I relationship after planned 44 aligners. The planning included power ridges on mandibular anterior teeth to obtain additional root torque as well as precision cuts on the maxillary canines (teeth 13 and 23) and button cut-outs on mandibular first molars (teeth 36 and 46) for Class II elastics. IPR was

planned on all mandibular teeth from mesial of the mandibular left to mesial of the right first molar (mesial 36 to mesial 46) (0.3 mm) and spaces were planned to be maintained in the maxilla distal of the maxillary lateral incisors (teeth 12 and 22) due to Bolton discrepancy.

Due to insufficient compliance with the aligner wear, the aligner showed insufficient fitting, particularly on maxillary canines, and additional aligners were necessary during the



Figs 27f to j Treatment goal after 44 aligners with distalisation in the maxilla to create space for alignment of teeth 13 and 23 and end in a Class I relationship. IPR was necessary on all mandibular teeth from mesial of tooth 36 to mesial of tooth 46 (0.3 mm) and planned final spaces distal of tooth 12 of 0.7 mm and distal of tooth 22 (0.8 mm). Button cut-outs were planned on teeth 36 and 46, and precision cuts on 13 and 23 for Class II elastics.



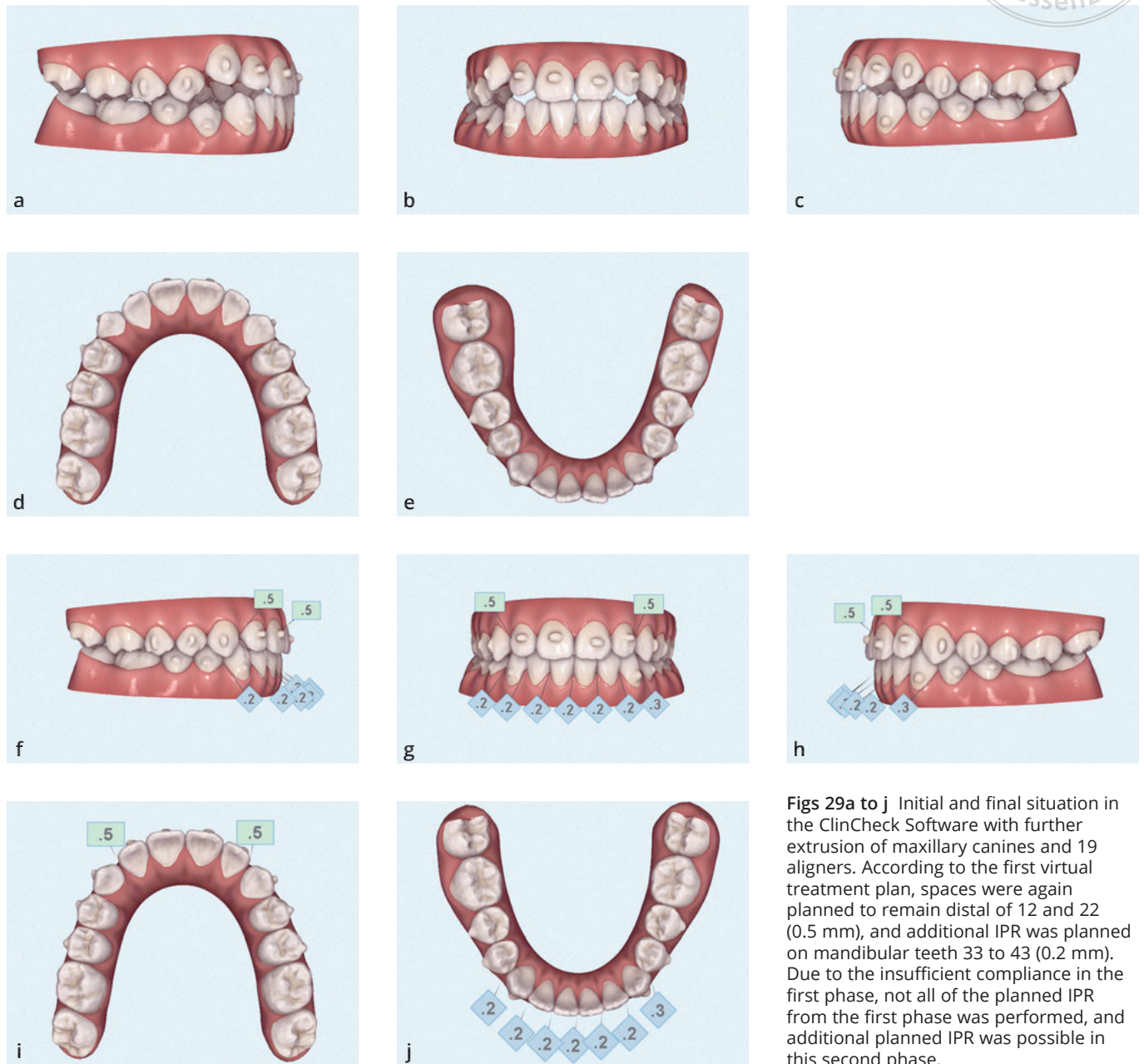
Figs 28a to e Intraoral situation after interruption of first phase at aligner 31 of the planned 44 aligners of the first phase of treatment. Insufficient patient cooperation and aligner wear meant there was a need for additional aligners. In particular, teeth 13 and 23 showed insufficient aligner fitting. To obtain better anchorage of anterior teeth, attachments were added on all maxillary anterior teeth and scans were taken again.



treatment course after 31 aligners (Fig 28). Figure 29 shows again the initial situation and the final planned virtual treatment outcome after a second aligner phase with additional 30 aligners. For better anchorage, attachments were also added on maxillary incisors (teeth 12, 11, 21 and 22) which are visible in the ClinCheck Software. Again, spaces were planned to remain distal of the maxillary lateral incisors (teeth 12 and 22) (0.5 mm) and additional IPR was planned

from the mandibular canine to canine (teeth 33 to 43) (0.2 mm). Due to the insufficient compliance in the first phase and the early start of the second phase, not all of the planned IPR from the first phase was performed, and additional planned IPR was possible in this second phase (Fig 29).

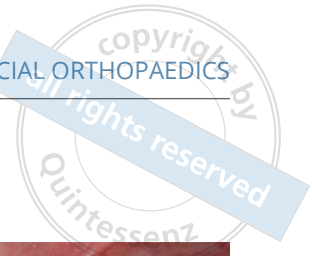
Figure 30 shows the intraoral situation after the second aligner phase. The patient was still not cooperating and



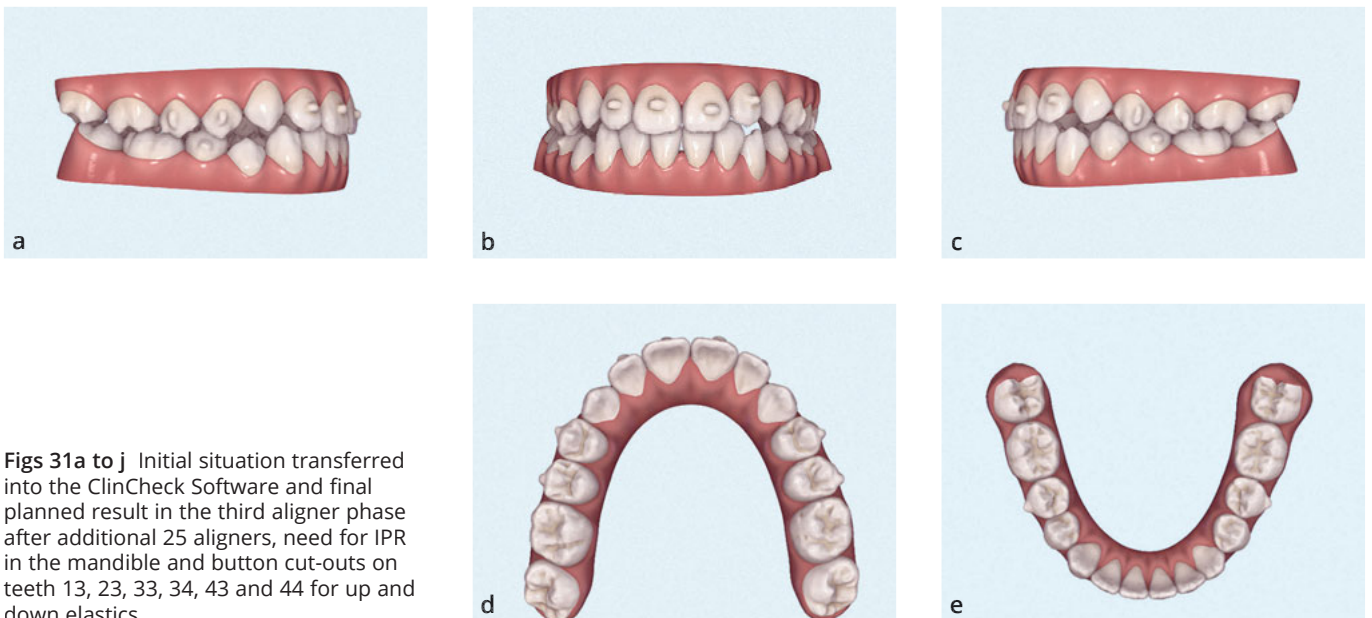
Figs 29a to j Initial and final situation in the ClinCheck Software with further extrusion of maxillary canines and 19 aligners. According to the first virtual treatment plan, spaces were again planned to remain distal of 12 and 22 (0.5 mm), and additional IPR was planned on mandibular teeth 33 to 43 (0.2 mm). Due to the insufficient compliance in the first phase, not all of the planned IPR from the first phase was performed, and additional planned IPR was possible in this second phase.

canines were not sufficiently extruded. After discussion for further treatment options with the patient's parents, it was decided to start with a last try of treatment phase including up and down elastics on maxillary canines to mandibular canines and first premolars to obtain optimal anchorage and achieve the planned final result. Figure 31 shows the initial situation transferred into the ClinCheck Software and

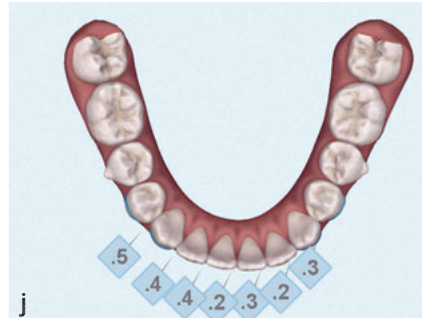
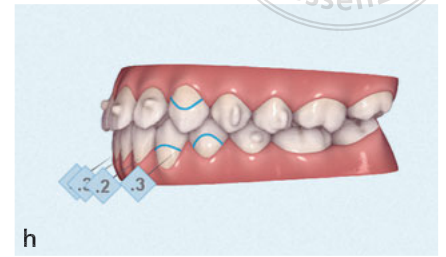
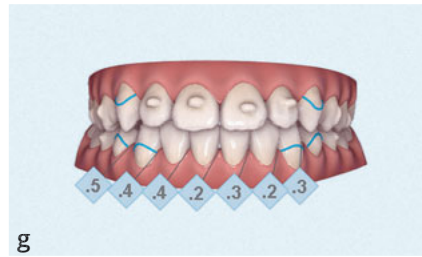
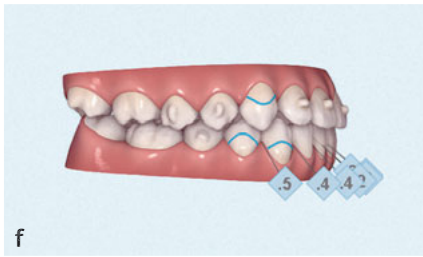
the final planned result in the third aligner phase after an additional 25 aligners, the need for IPR in the mandible and button cut outs on all canines and mandibular first premolars (teeth 13, 23, 33, 34, 43 and 44) for up and down elastics. Figure 32 shows the intraoral situation with aligners and up and down elastics on composite hooks on maxillary and mandibular left canines and mandibular left pre-



Figs 30a to h Intraoral situation after second aligner phase. The patient was still not cooperating and canines were not sufficiently extruded.



Figs 31a to j Initial situation transferred into the ClinCheck Software and final planned result in the third aligner phase after additional 25 aligners, need for IPR in the mandible and button cut-outs on teeth 13, 23, 33, 34, 43 and 44 for up and down elastics.



Figs 31a to j (cont.)



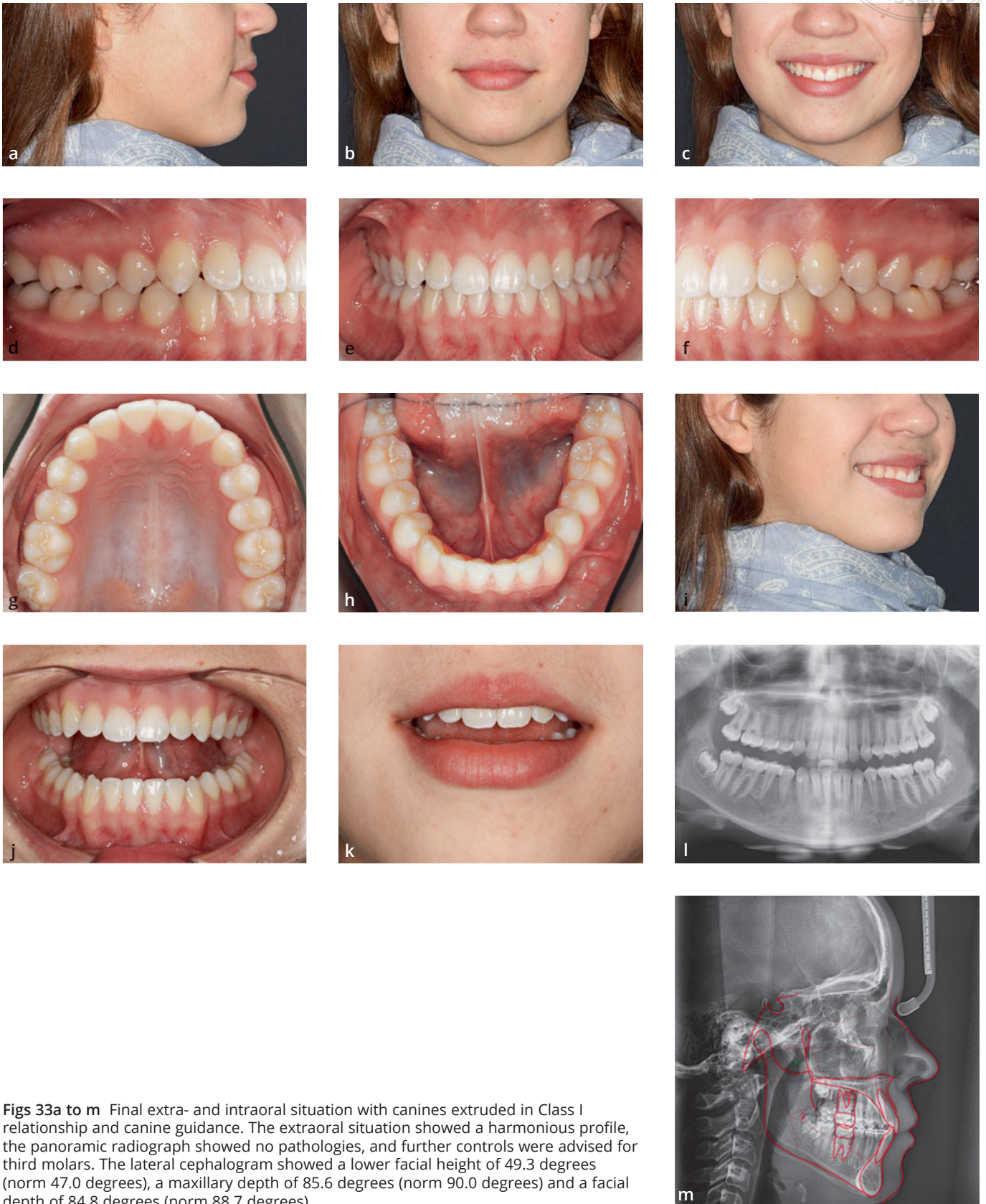
Figs 32a to c Intraoral situation with aligners and up and down elastics on composite hooks on teeth 13 to 43 and 44, and 23 to 33 and 34, in situ.

molar (teeth 13 to 43 and 44) and maxillary and mandibular right canines and mandibular right premolar (teeth 23 to 33 and 34) in situ.

The final outcome in Class I relationship and harmonious aligned arches is demonstrated in Fig 33 and Table 4. The panoramic radiograph showed no pathologies, all third molars were visible and further controls were advised. The lateral cephalogram showed a lower facial height with 49.3 degrees (norm 47.0 degrees), a maxillary depth of

85.6 degrees (norm 90.0 degrees) and a facial depth of 84.8 degrees (norm 88.7 degrees).

Overall aligner treatment time was 28 months and therefore quite a long treatment time due to insufficient patient compliance and need for several phases. Retention was performed with a lingual retainer from mandibular left to right first premolar (34 to 44) and a removable aligner in the maxillary arch.



Figs 33a to m Final extra- and intraoral situation with canines extruded in Class I relationship and canine guidance. The extraoral situation showed a harmonious profile, the panoramic radiograph showed no pathologies, and further controls were advised for third molars. The lateral cephalogram showed a lower facial height of 49.3 degrees (norm 47.0 degrees), a maxillary depth of 85.6 degrees (norm 90.0 degrees) and a facial depth of 84.8 degrees (norm 88.7 degrees).



Table 4 Final cephalometric results

Variable	Norm	Result 10 Jan 2018	Difference	Standard deviation
				5 4 3 2 1 0 1 2 3 4 5
Incisor horizontal overlap (mm)	2.5 ± 2.5	-2.5	-5.0	
Incisor vertical overlap (mm)	2.5 ± 2.0	3.9	1.4	
Interincisal angle (degrees)	130.0 ± 6.0	132.1	2.1	
Convexity of A (mm)	0.8 ± 2.0	0.8	0.0	
Lower facial height (degrees)	47.0 ± 4.0	49.3	2.3	
6. PTV distance (mm)	18.0 ± 2.0	17.0	1.0	
1- APo distance (mm)	1.0 ± 2.3	4.7	3.7	
1. APo distance (mm)	3.5 ± 2.3	6.8	3.3	
1- APo angle (degrees)	22.0 ± 4.0	22.4	0.4	
1. APo angle (degrees)	28.0 ± 4.0	25.4	-2.6	
XI-OcP (mm)	1.8 ± 3.0	0.6	-1.2	
XIPO-OcP angle (degrees)	24.5 ± 4.0	20.3	-4.2	
LL-E plane (mm)	-0.8 ± 2.0	-0.3	0.5	
Upper lip length (mm)	24.0 ± 2.0	32.5	8.5	
Lip embrasure – occlusal plane (mm)	-3.5	1.4	4.9	
Facial (angle) depth (degrees)	89.0 ± 3.0	84.8	-4.2	
Facial axis (degrees)	90.0 ± 3.0	88.3	-1.7	
Conical angle (degrees)	68.0 ± 3.5	64.1	-3.9	
Mandibular plane (degrees)	27.2 ± 4.5	31.1	3.9	
Maxillary depth (degrees)	90.0 ± 3.0	85.6	-4.4	
Maxillary height (degrees)	55.4 ± 3.0	56.1	0.7	
Palatal plane (degrees)	1.0 ± 3.5	0.7	-0.3	
Cranial deflection (degrees)	27.0 ± 3.0	23.8	-3.2	
Cranial length anterior (mm)	55.0 ± 2.5	54.9	-0.1	
Facial height posterior (mm)	55.0 ± 3.3	58.1	3.1	
Ramus position (degrees)	76.0 ± 3.0	75.2	-0.8	
Porion location (degrees)	39.0 ± 2.2	31.9	-7.1	
Mandibular arc (degrees)	29.0 ± 4.0	44.9	15.9	
Corous length (mm)	74.6 ± 2.7	63.0	-11.6	

Figure 34 demonstrates the course of treatment with the start of the functional appliance and myofunctional therapy (Figs 34d to 34f), followed by Invisalign treatment including Class II elastics (Figs 34g to 34i), followed by up and down elastics in the canine region, and Figs 34j to 34l show the final intraoral result. Extraorally, the patient demonstrates a harmonious profile after the treatment combination (Fig 34c).

Conclusion

Functional orthodontics followed by aligner orthodontics offers a comfortable treatment alternative for young patients with fewer potential side effects than former combinations with fixed appliances. The combination of both techniques at the same time allows shortening of the overall treatment time and inclusion of skeletal effects in the combined aligner treatment.



Figs 34a to l (a to c) Treatment course extraoral profile. (d to f) Start of treatment with functional orthodontics and myofunctional therapy. (g to i) Start of the Invisalign treatment. (j to l) Final situation after Invisalign treatment.



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